Zooplankton Aggregation Around Sills

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LONG-TERM GOALS

This project seeks to understand the biological and physical mechanisms for producing and maintaining dense aggregations of zooplankton in regions where ocean currents interact with steeply-sloping coastal sills.

OBJECTIVES

The primary goal during the first project year was to quantitatively assess zooplankton distributions and species in Knight Inlet, with special focus on the sill near Hoeya Head. During this first cruise, we used calibrated echosounders operating over a range for acoustical frequencies to document the temporal evolution of elevated scattering around the sill and we employed a new digital camera system called ZOOVIS to ground-truth the sources of enhanced scattering in the vicinity of the sill.

APPROACH

This work combined expertise in multi-frequency acoustics, conventional zooplankton trawls, and in situ optical techniques in a two-week field survey of Knight Inlet. Repeat transects across the sill with a vessel-based, three-frequency echo-sounder system were supplemented with multi-net (BIONESS) trawls and bongo nets (operated by D. Mackas and group of IOS), profiles with a new high-resolution camera system (ZOOVIS), and optical plankton counter casts (operated by R. Campbell and T. Ross, graduate students at the Univ. of Victoria). Additional broad-area acoustic and in situ surveys covering the entire length of Knight Inlet were conducted. Acoustic Doppler current-meter and inverted echo-sounder moorings were deployed just west of the sill, and CTD casts throughout the entire inlet were conducted.

WORK COMPLETED

A two-week field survey on board the *CCGS Vector* was conducted in Knight Inlet Nov. 12 to 25, 2001. A three-frequency (40, 100, and 200 kHz), narrow-beam echo-sounder system was built and tested by the IOS Acoustical Oceanography group, and then operated by M. Trevorrow during the field trials. This system was utilized for both transects across the sill and wide-area surveys in other areas of the inlet and provided a near-synoptic view of the distributions of sound-scattering particles in the water column. ZOOVIS (Fig. 1) and other systems (BIONESS multi-net and optical plankton counter) were deployed while acoustic systems were operating to determine the composition of the water column.

ZOOVIS was deployed from the CCGS Vector in two configurations: horizontal and downward imaging. Deployment locations are illustrated in Fig. 2. Data from a cast on November 21, 2001 that employed the downward imaging configuration are presented in this report. A series of optical casts were collected on November 21 during concurrent acoustic surveys.. One cast recorded shortly after midday (Fig. 3) provides an illustration of the kind of data collected by ZOOVIS and its application to interpretation of echograms and zooplankton ecology. The instrument was deployed from the stern and a pair of profiles were collected between the surface and 166m (Fig. 3). The image volume was 443 ml (10.95 cm x 10.95 cm x 3.69 cm) and images were recorded at 0.25 Hz while ZOOVIS was lowered at approximately 50 cm s^{-1}. Following the profiles, the vessel began to steam into the current at 0.5 – 1.0 knots and a series of towyos were performed at mid-depth with vertical velocities ranging from 17.4-57.5 cm s^{-1}. Image acquisition was suspended at 142 m and ZOOVIS was recovered (Fig. 3).

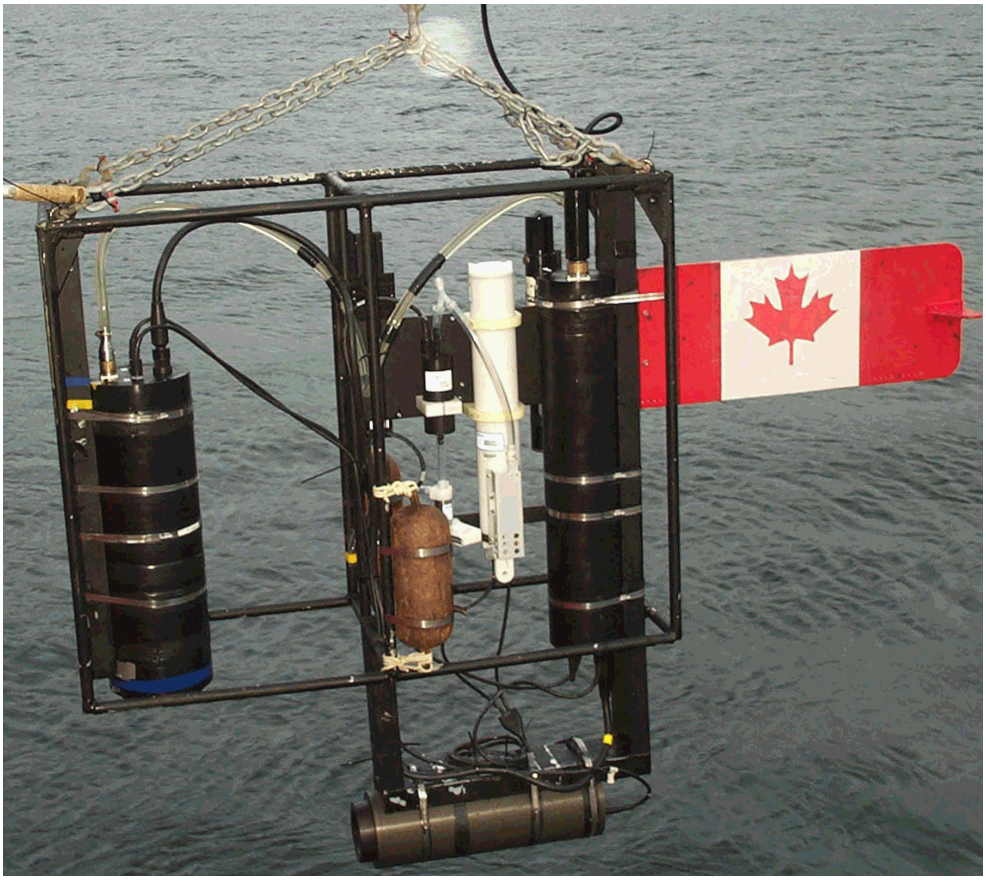

Figure 1. ZOOVIS prior to deployment from the CCGS Vector in Knight Inlet. The system is configured in a downward-looking mode.

Images were corrected for the heterogeneous background illumination, thresholded and converted to 8 bit images prior to image analysis. The image analysis software was used to locate and measure all particles with areas greater than 0.2 mm^2. Recognizable targets (primarily euphausiids) were identified to lowest taxonomic level possible. Densities of euphausiids were estimated by dividing the numbers of individuals by the volume imaged within each depth stratum or acoustical feature. The degree to which targets were aggregated or dispersed in each image was evaluated statistically using a refined nearest neighbor analysis (Boots and Gettis, 1988) that tests the null hypothesis that the distribution of targets in each image was not different from a completely spatially random distribution.

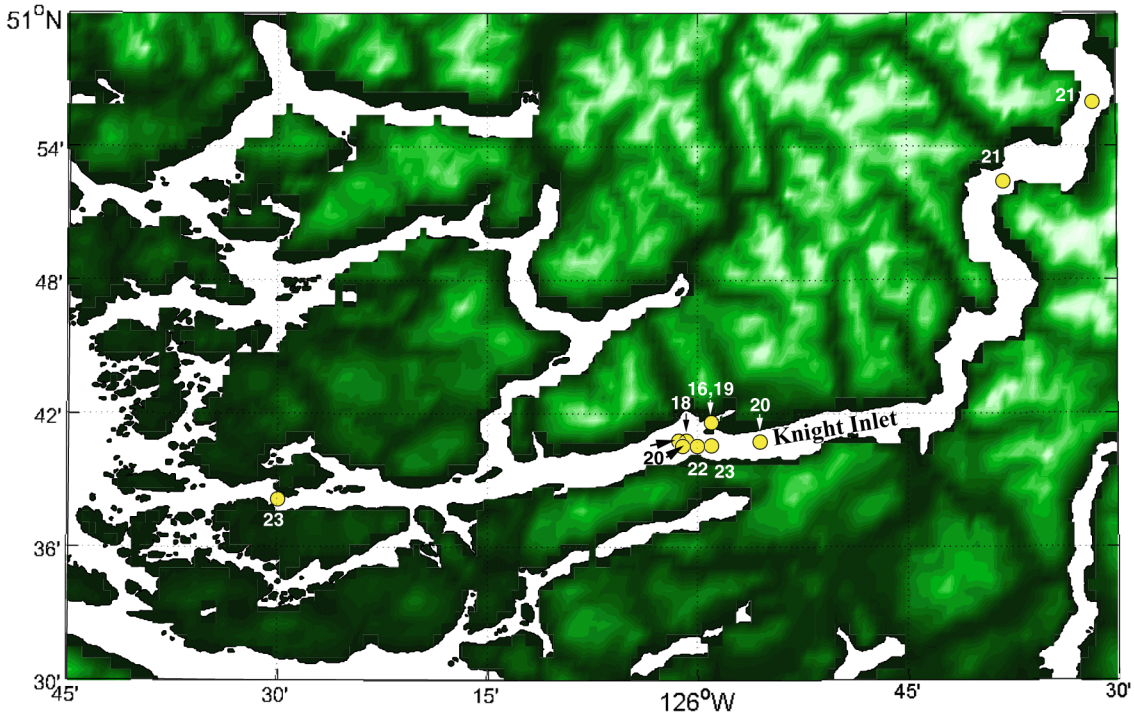

Figure 2. Map of Knight Inlet illustrating locations where ZOOVIS casts were collected (●). Each cast location is number by the day of the month on which it was collected.

RESULTS

At the field of view selected for most Knight Inlet operations (10.95 x 10.95 cm x 3.3 cm), ZOOVIS provided clear images (Fig. 4) of particles larger than 2 mm length from a distance of approximately 40 cm. Smaller targets were also imaged, however, anatomical details of small targets such as copepod antennae were not always visible. Sufficient resolution of sub-2mm targets was usually available to determine their shape and likely identity (e.g. copepods, phytoplankton colony, marine snow).

Most larger targets were detected in a region of elevated acoustical scattering located between approximately 60-120 m (Fig. 3) and these were primarily small euphausiids (<10 mm long) believed to be *Euphausia pacifica* (Fig. 4). No euphausiids were detected outside the subsurface region of elevated scattering. Images of euphausiids were clear and provided unambiguous information from which to estimate their probably taxonomy, size and orientation. Based on the volume of water imaged between 60 and 120 m (132.9 L), the density of small euphausiids within the layer was 52.7 m^{-3}. Elevated acoustical scattering at approximately 10m depth did not appear to be related to the presence of zooplankton-sized particles (Fig. 4) and was likely due to turbulence.

IMACT/APPLICATIONS

Profiling instruments such as ZOOVIS have applications in a variety of regions that would prove problematic for towed instruments. The fjord system we examined was characterized by steep bathymetry and abrupt changes in depth that would pose a hazard for towed systems. Risks of fouling or colliding with fixed structures are also inherent problems when sampling around ice flows, from petroleum platforms, and around natural reefs. Providing that the depth of the bottom and locations of

fouling structures are known, ZOOVIS can be safely operated in such areas. The ship's echosounder provided a good estimate of the safe working depth beneath the vessel in Knight Inlet and permitted ZOOVIS to be deployed to within a few meters of the bottom on several occasions. The visible presence of ZOOVIS in the echosounder also assisted us in guiding the vehicle into the appropriate scattering layers. More importantly, understanding the relationship between observed scattering patterns and the underlying distributions of sound-scattering particles is a central problem in acoustical oceanography. The use of the camera system in Knight Inlet provides a means of verifying the composition of the sound scattering layers in the vicinity of the sill on spatial scales comparable to those of the acoustics.

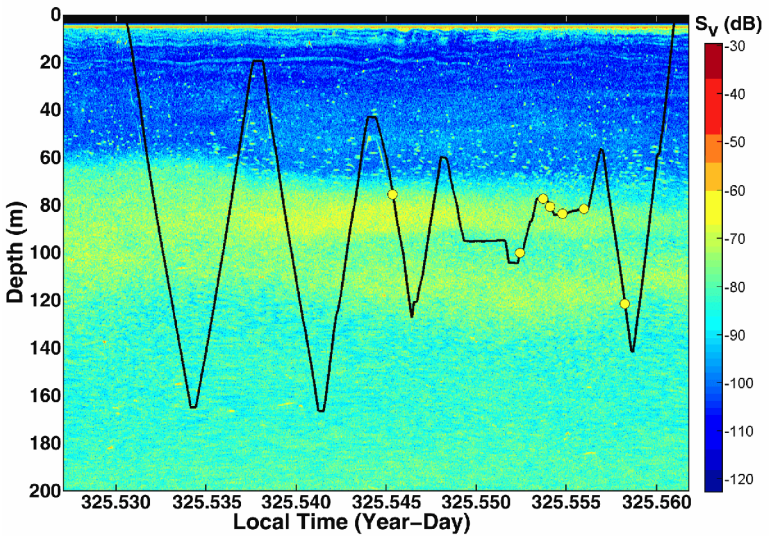

Figure 3. Trajectory of ZOOVIS (black line) superimposed on the 200 kHz acoustical record. The yellow circles indicate locations where small euphausiids (presumeably <u>Euphausia pacifica</u>) were imaged by ZOOVIS.

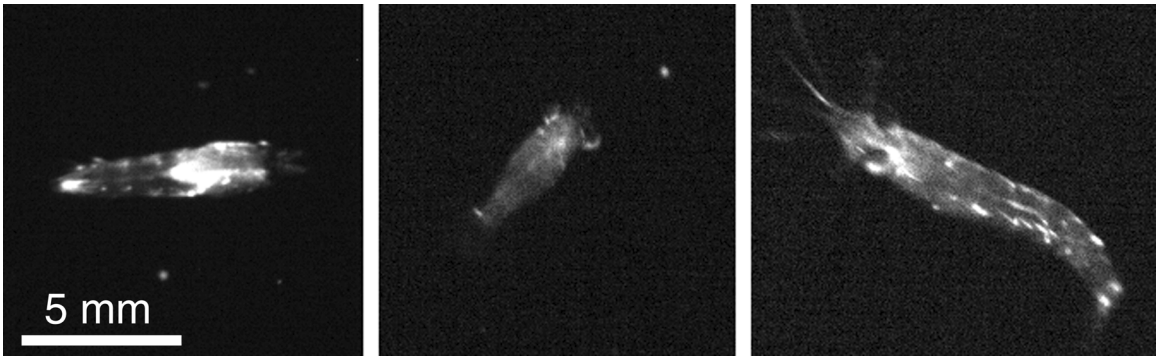

Figure 4. Examples of euphausiids imaged by ZOOVIS. The images of these small ~8 mm long animals have been cropped from the full-field ZOOVIS images.

The performance of ZOOVIS appears promising. Further analysis of the complete Knight Inlet dataset and intercomparisons with BIONESS casts and acoustic data will be required to assess potential biases of the system due to avoidance, however, the system yielded high-quality images of mesozooplankton and operated well in a fjord system. It appears to have met its design criteria for a system capable of

quantifying the distributions and abundances of mesozooplankton in coastal waters. We have completed improvements in the frame (Fig. 5) utilizing a smaller and "stealthier" design that allows rapid adjustments to focus and illumination and are working on increasing network bandwidth (gigabit Ethernet). Ultimately, as digital camera technology evolves, improvements in the resolution of the camera will add capabilities to what is already a flexible instrument capable of quantitatively surveying a wide range of mesozooplankton in the coastal oceans.

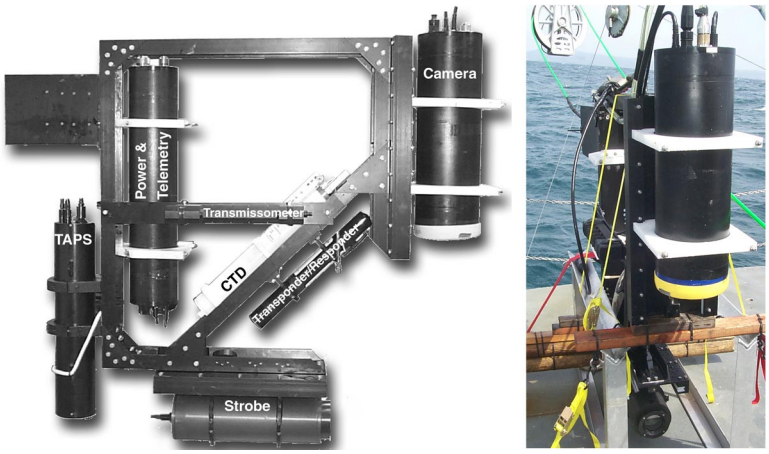

Figure 5. (Left) The new ZOOVIS frame constructed of anodized aluminum channel. The camera and strobe are mounted on moveable plates for rapid focus and illumination adjustments. A stabilizing fin is not shown. (Right) ZOOVIS on the stern of R/V Elakha off Newport Oregon.

RELATED PROJECTS

ZOOVIS was prepared for work off Newport, Oregon in April and May, 2002. This research was in collaboration with Dr. Timothy Cowles and Ms. Malinda Sutor (College of Oceanic and Atmospheric Sciences, Oregon State University) and was designed to utilize ZOOVIS to quantify the distributions and abundances of mesozooplankton within thin-layers. Weather conditions and power supply problems associated with using ZOOVIS from a small vessel (Fig. 5) prevented us from deploying the system, however, plans are try again in 2003 from a larger vessel. During November 2002, we will utilize the modified ZOOVIS system in Knight Inlet for the second cruise to examine acoustical scattering in the vicinity of the sill.

A collaboration between BAE Systems Inc. (N00014-00-D-0122) and LSU (N00014-01-1-0305) is developing scattering models based on high-resolution digitizations of zooplankton. Images from ZOOVIS contain sufficient detail to be digitized and modelled using this approach. We plan to begin with images of euphausiids collected in 2001.

PUBLICATIONS

Benfield, M.C., C.J. Schwehm, R.G. Fredericks, G. Squyres, S.F. Keenan, and M. Trevorrow. In Press. ZOOVIS: A high-resolution digital still camera system for measurement of fine-scale zooplankton distributions. In, P. Strutton, and L. Seuront (eds.) Scales in Aquatic Ecology: Measurement, Analysis and Simulation. CRC Press. Accepted for Publication June 2002.